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shaft to minimize friction effects and related wear; and (4) providing a seal between the lubricated assembly and the turbine and compressor housings.

Because the rotary action of the turbine is dependent upon the heat and volumetric flow of exhaust gas exiting the engine, turbochargers are often of reduced effectiveness when the engine to which they are coupled is run at a low speed. The reduced effectiveness is often labeled turbo-lag. In order to overcome turbo-lag during operating conditions when the heat and volumetric flow of exhaust gas is low, an electric motor can be used to rotate the shaft and induce the compressor to spin at high speed.

An electric assisted turbocharger is capable of spinning at high speeds when the associated engine is running at very low speeds, or not running at all. During these operating conditions it is very possible that the pressure and flow of lubricating oil to the turbocharger bearing will be insufficient. Insufficient oil flow during high speed electric assisted operation of turbocharger may cause permanent damage to the bearing system. Therefore, it is desirable that a system be devised for detecting/monitoring the flow of lubricating oil to the turbocharger bearing, and for preventing and/or controlling the spinning of the turbocharger shaft when the monitored oil pressure and flow are inadequate.

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SUMMARY OF THE INVENTION

A turbocharger control system of this invention is used with turbochargers comprising an electric assist motor for controlling the speed of the turbocharger, to provide desired engine operating characteristics, during engine operation. The system comprises an oil pressure sensor that is attached to the turbocharger at a location capable of receiving oil pressure information of lubricating oil being directed into the center housing for lubricating the shaft bearing assembly. The pressure sensor is configured to provide oil pressure information to a control system that is configured to control the operation of the electric motor and/or other operating parameters of the turbocharger and/or the vehicle.

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5 In an example embodiment, the control system comprises an engine control unit and a motor controller, that are configured to regulate and/or disable operation of the electric motor (thereby controlling the extent of electric assist to the turbocharger) during operating conditions where a low oil pressure condition is detected when compared to a predetermined minimum. The control system is configured to
10 reactivate the electric motor once a desired minimum oil pressure has been detected by and transmitted from the pressure sensor.

Configured in this manner, turbocharger control systems of this invention operate to prevent possible damage to the turbocharger shaft bearings, thereby extending the effective service life of the turbocharger.

15 BRIEF DESCRIPTION OF THE DRAWINGS

The aspects of the present invention are more readily understood when considered in conjunction with the accompanying drawings and the following detailed description wherein:

20 FIG. 1 is a schematic diagram illustrating an electric assisted turbocharger control system, constructed according to principles of this invention, employing an oil pressure detector attached to the turbocharger; and

FIG. 2 is a cross-sectional view of an electric assisted turbocharger constructed according to an embodiment of the present invention.

25 DETAILED DESCRIPTION

Electric assisted turbochargers, constructed according to principles of this invention, comprise an oil pressure sensor in oil flow communication with lubricating oil that is directed to the turbocharger shaft bearing. Control means are connected to
30 the oil pressure sensor and are configured to provide a control signal output in response to detected low lubricating oil pressure. The control signal output can be used to, among other things, to control the speed of the electric motor, i.e., reduce or stop the turbocharger electric assist, when a low pressure condition is detected, thereby minimizing and/or eliminating the possibility of shaft bearing damage and
35 extending turbocharger service life.

5 As shown in FIG. 1, an electric assisted turbocharger 10, constructed according to the principles of this invention, generally comprises an electric motor 12 that is disposed around a turbocharger shaft 14 that is common to both the turbine 16 and the compressor 18. The Electric motor 12 is disposed within the turbocharger adjacent the center housing 20, and is interposed axially between the center housing
10 20 and a compressor housing 22 that houses the compressor 18.

 A turbocharger shaft bearing assembly (not shown) is disposed around the shaft and is located within the center housing 20. The center housing is configured having oil passages disposed therein for directing lubricating oil to the shaft during turbocharger operation. The lubricating oil is typically provided by the engine that is
15 being turbocharged, thus is pressurized by the engine oil pump and operation of the engine.

 Electric assisted turbochargers of this invention comprise an oil pressure sensor 24 that is attached to the turbocharger, e.g., at the center housing, and is in oil flow communication with the lubricating oil bearing directed to the shaft bearing
20 assembly. The oil pressure sensor 24 provide oil flow pressure information to a control system 26 for purposes of controlling the operation of the turbocharger and, if desired, other vehicle parameters, in the event of a detected low oil pressure condition. In an example embodiment, the control system 26 can be configured to control an engine Electronic Control Unit (ECU) 28 and a turbocharger electric motor
25 controller 30.

 If, during operation of the turbocharger, the oil pressure monitored by the oil pressure sensor 24 and communicated to the control system 26 falls below a predetermined minimum pressure, the control system 26 is configured to disable the electric motor 12 providing the electric assist to the turbocharger, thereby reducing
30 shaft rotational speed until such time as the detected oil pressure rises back above the predetermined minimum pressure. Configured in this manner, the oil pressure sensor (when used in combination with the control system) functions to prevent damage to the turbocharger shaft bearing that could occur during operation under conditions of inadequate oil pressure.

35 Referring now to FIG. 2, an example electric assisted turbocharger embodiment of this invention comprises (moving axially from left to right) the

5 compressor 18 disposed within the compressor housing 22. To the right of and attached to the compressor housing is a motor housing 32 that contains the electric motor 12. To the right of and attached to the motor housing 32 is the center or bearing housing 20. A bearing assembly 34 is shown disposed within the center housing 20 and positioned around the common shaft 14.

10 To the right of and attached to the center housing 20 is a turbine housing 36 that houses the turbine 16. Together, the motor housing 24 and the central housing 26 have a central opening extending axially from the compressor 20 to the turbine 16, or alternatively to a turbine and/or compressor backplate. The compressor 18 is attached to one end of the shaft 14, and the shaft projects through central openings of the
15 compressor housing 22, motor housing 32, center housing 20, and turbine housing 36, and is attached at its opposite end to the turbine 16.

As briefly discussed above, the oil pressure sensor 26 is attached to the turbocharger at a position that enables oil flow communication with the lubricating oil being directed to the bearing assembly 34. In an example embodiment, the oil
20 pressure sensor 24 (shown schematically for purposes of reference) is attached to the center housing 20 proximate to an oil inlet 38 (shown schematically for purposes of reference). Thus, lubricating oil being directed to the center housing 22 passes into the oil inlet 34, is communicated to the oil pressure sensor 24, and is directed through the center housing to the bearing assembly for lubricating the shaft.

25 Referring again to FIG. 1, the oil pressure sensor 24 is connected to the control system 26 for providing an oil pressure indication thereto. In an example embodiment, during turbocharger operation, the oil pressure sensor 24 is configured to send an electrical signal at a designated time interval to the control system 26, indicating the pressure of lubricating oil entering the center housing. The control
30 system 16 is programmed having a logic circuit that regulates the operation of the electric motor 12 (of the electric assist turbocharger 10) based upon the received oil pressure information provided by the oil pressure sensor 24.

If the oil pressure sensor 24 transmits an oil pressure level that is equal to or higher than a preselected oil pressure, the control system 26 allows the turbocharger
35 electric motor 12 to operate normally. If, however, the oil pressure sensor 24 transmits an oil pressure level that is below a preselected oil pressure, the control

5 system 26 does not provide power to the electric motor 12, thus disabling operation of the electric motor 12. By disabling operation of the electric motor 12, the control system slows rotational operation of the turbocharger shaft to minimize and/or prevent undesired shaft damage caused from underlubrication.

10 Once the control system 26 has disabled operation of the electric motor 12, it continues to receive oil pressure readings from the oil pressure sensor 24. Once the control system 26 receives a signal from the oil pressure sensor 24 indicating that the oil pressure entering the center housing is equal to or higher than the preselected oil pressure, the control system 26 resumes normal operation of the electric motor 12 to provide the desired electric assist.

15 In another embodiment of the present invention, additional sensors can be employed to assess additional operating conditions of the turbocharger 10. Such additional sensors are also electrically connected to the control system 26 for purposes of simply monitoring such operating conditions, and providing an output control signal for purposes of controlling on or more operating parameter of the turbocharger or vehicle. In an example embodiment, the additional sensors may include a
20 lubricating oil temperature sensor (to monitor the temperature of the oil being directed to or away from the shaft bearing assembly) and a turbocharger speed sensor (to monitor the rotational speed of the turbocharger shaft). The control system can be configured to control the electric motor 12 according to a plurality of preselected
25 sensor values.

Having now described the invention in detail as required by the patent statutes, those skilled in the art will recognize modifications and substitutions to the specific embodiments disclosed herein. Such modifications are within the scope and intent of the present invention.